Climate Effects on Radial Growth in Ash
at the Lakeside Laboratory Site in Iowa

An Honors Thesis (HONR 499)

By

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Abstract

The objective of this study was to determine what climate variables most strongly influence radial growth of white ash (*Fraxinus americana* L.) at the Lakeside Laboratory site in Iowa, near the northwest corner of the species range and to evaluate white ash and northern red oak (*Quercus rubra* L.) as a functional group for climate modeling. Tree ring measurements were taken for 28 cores representing 14 trees sampled at the site. Measurements were correlated with monthly and seasonal values for climate variables including temperature, precipitation, and drought index. There was no indication that early wood formation was influenced by these climate variables. Latewood formation was significantly negatively correlated with spring temperatures and was positively correlated with precipitation in the previous winter and the current summer and Palmer drought index for the previous winter through the current summer. These correlations coefficients were compared with results from a previous study of growth-climate correlations for northern red oak at a site 24 kilometers east of Lakeside Laboratory. White ash radial growth was more sensitive to spring temperatures while red oak was more sensitive to summer temperature. White ash and red oak showed similar growth-climate responses to precipitation and Palmer drought severity index. These results will be interpreted in the context of white ash growth at the extent of its distribution.

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Introduction

With the spread of the emerald ash borer (*Agrilus planipennis* Fairmaire), it is likely that white ash trees will become ecologically extinct within the next few decades (Knight et al., 2012). Very little research has been done on white ash growth-climate relationships (Lockwood, 2014), and mature stands of white ash available for study are becoming fewer in number. The USDA predicts a large reduction in white ash habitat distribution over the next 80 years due to climate change (Landscape Change Research Group, 2014). Because of the scarce data available and the limited time frame in which to sample white ash, it is important to investigate how they respond to climate variables.

Recent studies suggest trees with similar biology and ecology may respond similarly to climate factors (Cook, 2001; Lockwood 2014; LeBlanc & Stahle 2015; LeBlanc & Terrell 2009, 2011). By comparing samples of white ash and red oak from nearby sites, more direct comparisons about growth-climate responses can be made. LeBlanc and Terrell (2009 and 2011) hypothesize that temperate zone deciduous tree species with preformed apical growth patterns and ring-porous wood anatomy should have similar growth responses to climate and can be treated as functional groups for forest modeling. They also suggest criteria for establishing functional groups. The criteria are spatial replication of the observed associations and a plausible cause-effect mechanism for the associations.

The objectives of this study are to identify the most important climate variables for radial growth of white ash trees at the extent of their range, and to compare the results to red oak data to investigate the plausibility of functional grouping. Our hypothesis is that if oak species show similar responses to climate across their range, and if white ash and white oak show similar responses at sites in Indiana, then white ash and red oak will show similar growth responses to climate at similar sites in Iowa.

Description of Study Site

The white ash cores used in this study were obtained from the Lakeside Laboratory, located in the northwestern portion of Iowa at coordinates 43.38° N, 95.18°W. This site is in the northwestern extent of the distribution of white ash trees in North America. The predominant soil type on the site is loam, and there is a 0-10% slope and east aspect. The red oak data was obtained from samples taken for the Leblanc and Terrell 2011 study, from Fort Defiance State Park 24 kilometers away from the Lakeside Laboratory. The coordinates for Fort Defiance State Park are 43.39° N, 94.67° W. The predominant soil type on this site is loam, and trees were sampled on 20-40% slopes with a north-northeast aspect.

Methods

Sources of tree-ring data

The white ash data was obtained from 28 cores representing 14 trees from the Lakeside Laboratory site in Iowa. Selected trees were at least 50 years old, showed no signs of damage or recent competitive release, and were either of the dominant or co-dominant crown class. Cores were taken by David LeBlanc in the summer of 2014.

Tree-ring chronology development

The tree-ring chronologies were developed following the methods described by LeBlanc and Terrell (2009, 2011). Prior to measurement, all cores were dated visually, counting back from the year the sample was taken, 2014, to the last complete annual ring. These dates were cross-checked using marker rings. Marker rings are narrow annual rings that are replicated in many trees due to regional drought, and are distinguishable by their size and location within the core. The cores were measured to 0.01mm precision using J2X software on a Velmex measuring table. Measurements were taken for earlywood and latewood, and the sum of the two measurements was used as a measurement for total ring width. After measurement, the program COFECHA was used to identify cross-dating and measurement errors. COFECHA indicated individual cores where correlation with the mean chronology was low. The data for these cores was checked visually to see if marker rings corresponded to known drought years. All cores that were flagged by COFECHA showed marker rings that matched the rest of the series, so no cores were dropped. Ring-width chronologies for all cores were restricted to a common period from 1941-2013 and processed with the ARSTAN program using a 50-year smoothing spline. This removed maturation related reduction in ring width as well as temporal autocorrelation and produced a mean ring-index chronology.

Sources of Climate Data

This study of white ash growth-climate associations utilized the climate databases described in LeBlanc and Terrell (2009, 2011). This includes data for mean monthly temperature (T), mean monthly maximum (daytime) temperature (MxT), mean monthly minimum temperature (MnT), monthly precipitation (P), and monthly Palmer drought severity index (PDSI). Data for P, T, and PDSI were obtained from the National Climate Data Center. MxT data were obtained from the United States Historical Climatology Network. Seasonal climate variables were computed as the average of monthly values for prior summer (June, July, August), prior autumn (September, August), prior autumn (September, October, November), prior winter (December, January, February), current spring (March, April),and several variations of growing season months (May, June, July; June, July, August; May, June, July, August). Annual averages were computed as the average for a 17 month period from prior June through current October.

Analyses of Radial Growth - Climate Relationships

Simple Pearson product-moment correlation analyses were performed between the ARSTAN ring index chronology and the monthly, seasonal, and annual climate variables for the 17 month period between the prior June to the current October of the year the annual ring was produced. The benchmark for a significant correlation in the white ash chronology was $|r| \geq 0.232$, equivalent to $p=0.05$ for the number of years common to all cores in the Lakeside Laboratory white ash sample, $n= 73$. The benchmark for a significant correlation when comparing the white ash and the red oak chronologies was $|r| \geq 0.240$, equivalent to $p=0.05$ for the number of years shared between the two samples, $n= 57$.

Results

White ash earlywood width did not show many significant correlations with climate variables. Earlywood width was negatively correlated with MxT in May and September (Figure 1). In general correlations for MnT, T, and MxT were the same for earlywood, latewood, and total ring width, but MxT consistently shows the strongest correlations. Earlywood width was not correlated with precipitation in any month. Earlywood width was positively correlated with PDSI in the prior July, prior August, current May and June, and both the prior summer and current summer seasonal periods.

Latewood width was negatively correlated with MxT in the prior August, current March and April, as well as during the prior winter, current spring, and annual periods (Figure 1). Latewood width was positively correlated with precipitation in the prior July, current January, February, April, and June, and during all seasonal periods except the spring. Latewood width was positively correlated with PDSI from the prior October through current September and during all seasonal periods except for prior summer. White ash latewood width and total ring width showed nearly identical correlation values for all climate variables.

White ash and red oak showed many similar correlations between total ring width and climate variables. Both species showed a negative correlation between total ring width and MxT in March as well as during the spring and annual periods (Figure 2). Both species showed positive correlations between total ring width and precipitation in June and January, as well as during the prior autumn, prior winter, summer, and annual periods. Both species show positive correlations between total ring width and PDSI from the prior November through the current September, and during the prior winter, current spring and summer, and annual periods.

The correlations between total ring width and MxT were the largest difference between the two species. White ash total ring width was negatively correlated with MxT in April while red oak total ring width was not negatively correlated with MxT in April but it was in May, June, and September (Figure 2).

Fig. 1 Comparisons of growth-climate correlations between total ring width, latewood width, and earlywood width. Temperature correlations are negative, and so the scale is inverted. The X axis labels correspond to monthly and seasonal periods for which climate data was collected. Seasonal periods are abbreviated as follows: prior summer (pSm), prior autumn (pAt), prior winter (pWn), spring (Spr), summer (Sum), and annually (Ann). The red line indicates the benchmark of significance for the white ash data where $|r| = 0.232$, $p = 0.05$.

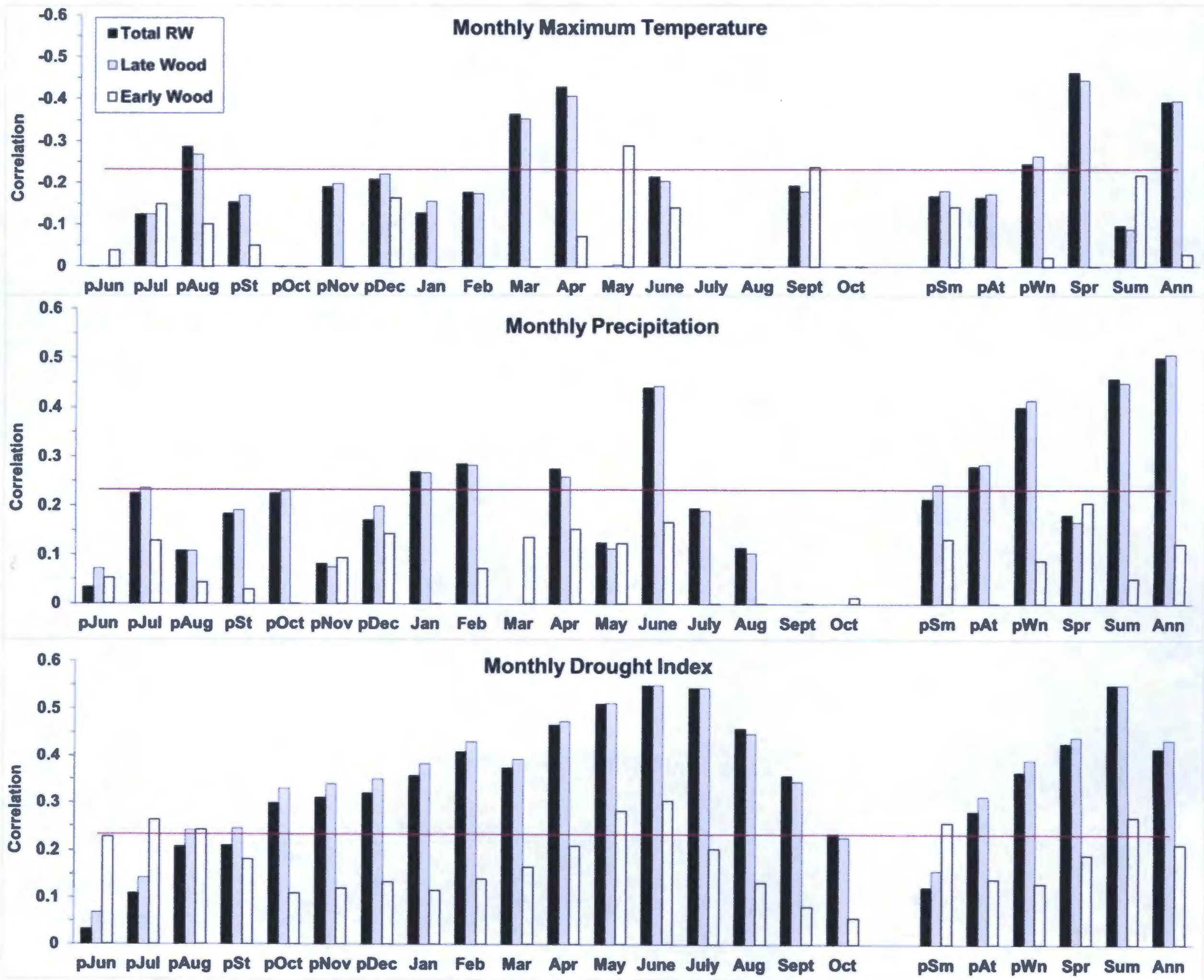
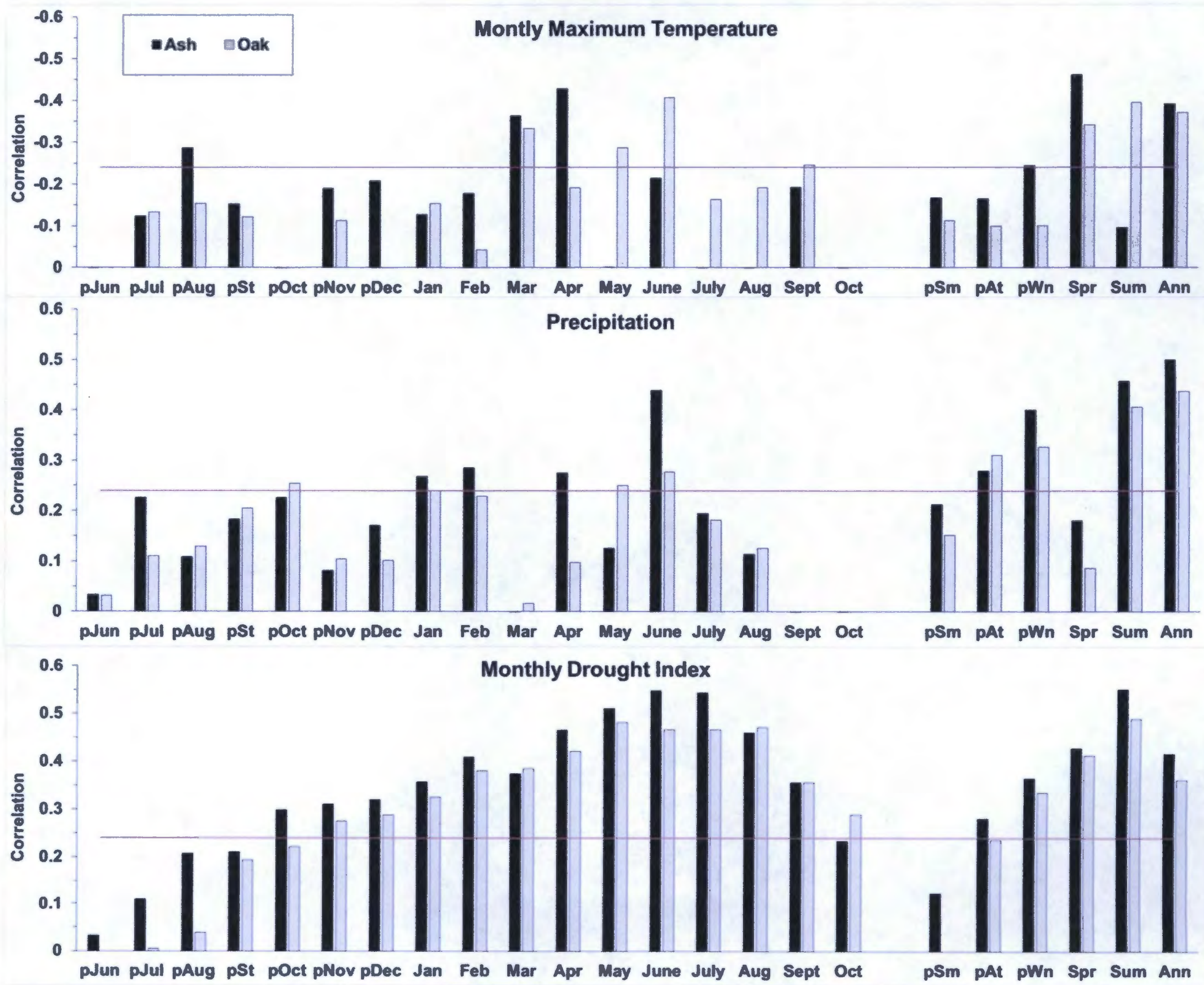


Fig. 2 Comparisons of total ring-width correlations for the overlapping chronologies of white ash and red oak data. Temperature correlations are negative, and so the scale is inverted. X axis abbreviations are the same as Figure 1. The red line indicates the benchmark of significance for the common period shared by white ash and red oak chronologies where $|r| = 0.240$, so $p = 0.05$.



Discussion

White ash earlywood width in this study showed very few significant correlations with climate variables. This low sensitivity to climate is possibly a mechanism to ensure that enough water can be transported to the crown prior to leaf out and latewood formation. In oak species, which are also ring-porous, over 90% of vessels are ruptured during the first freeze event in the fall, and hydraulic conductivity is restored when new earlywood vessels mature (Sperry et al., 1994; Cochard & Tyree, 1990). Because of the similarities in wood anatomy between white ash and oaks, it is plausible that white ash also must replace the majority of its vessels annually. In these species, low earlywood sensitivity to climate variation is beneficial to maintain the hydraulic conductivity for continued survival. Another reason for the lack of correlation between earlywood width and current year climate could be because of how earlywood is produced. Earlywood formation is supported by stored carbohydrates from the late growing season of the year before, and so is not dependent on current climate variables (LeBlanc & Terrell, 2011). There are weak positive correlations between earlywood width and PDSI in the late growing season of the year prior that support this reasoning. Latewood and total ring width do not show positive correlations with prior summer PDSI, which also suggests that growth habit is a plausible cause of the correlation between earlywood and prior summer PDSI. Lockwood (2014) also found earlywood to be very weakly correlated with climate variables.

White ash latewood width was negatively correlated with MxT in spring. This could be due to loss of hardiness against the cold when relatively warm spring days are followed by cold nights and frost events. According to Augspurger (2009), spring frost can damage developing leaves, reducing growth by lowering photosynthetic capacity and the frost-damaged trees may also use stored energy for refoliation instead of radial growth. Cochard and Tyree (1990) report *Quercus* species as particularly susceptible to short frosts and hypothesize that other ring-porous trees would have similar vulnerability. This negative correlation is likely due to regional climate as it appears in the red oak data from this study, but not in white ash sampled at sites in Indiana (Lockwood, 2014).

White ash latewood width was positively correlated with precipitation in the prior autumn and prior winter, April, and most strongly in June. Precipitation is a major determinant in water availability, and water must be available along with energy for plants to grow (Stephenson, 1998). The correlation with winter precipitation could be due to the soil characteristics of the region. LeBlanc and Terrell (2011) found that many sites in the northwest portion of red and white oaks' range were positively correlated with prior autumn and prior winter precipitation. The study suggested this was due to variable dormant season precipitation, deep soils, and large soil-water holding capacity. This could affect the amount of soil water available for growth in the early growing season. The red oak data from our study represent one of these northwestern sites and show a similar positive correlation with prior autumn and winter precipitation, while white ash from sites in Indiana do not (Lockwood, 2014).

White ash latewood and total ring width are positively correlated with PDSI in most months within the 17-month period included in this study. PDSI is an indicator of soil-water balance and reflects the amount of water available for transpiration and growth. Correlation strength increases from the winter to the summer, with a maximum correlation value in June ($r = 0.5489$). Calculation of PDSI inherently contains autocorrelation from month to month as soil-water balance is a running sum (LeBlanc & Terrell, 2009). This suggests that the actual strongest correlation between ash total ring width and PDSI occurs during May, not June. White ash sampled at sites in Indiana show a similar response to PDSI, with positive correlations from February through October (Lockwood, 2014).

The largest difference between white ash and red oak response to climate was that red oak total ring width was negatively correlated with MxT in the summer while white ash total ring width was not. One possible explanation for this difference is that the Lakeside Laboratory site experiences a mediated summer temperature because of its proximity to Okoboji Lake. Lakes can act as a heat sink, moderating the local temperature and causing a late spring and mild summer (Magnuson et al., 1997). This delay of warm temperatures may also account for the negative correlation between white ash total ring width and April MxT that is not present in red oak. The white ash may still be susceptible to frost damage after warm spring days into April, while the red oaks have entered the frost-free period.

White ash and red oak showed similar seasonal correlations for most climate variables included in this study. This similarity supports the hypothesis that species with similar wood anatomy and ecological characteristics have similar growth responses to climate (Lockwood, 2014). There are plausible cause-effect mechanisms for both the similar and different responses to climate variables between the two species. However, there are possible site-specific effects causing differences between white ash and red oak, as well as possible regional differences in response between white ash at the Lakeside Laboratory and in Indiana. Increased spatial replication is necessary to fulfil the criteria of white ash and red oak as a functional group.

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